TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1.Team interviewer: ______J. J. Smith______________________________
Date of interview: ____Sept 17, 1999______________

2. Name of technology __Tiltrotor Technology__(XV-3, XV-15)
The Tiltrotor projects were both part of the related technology of tiltrotor aircraft. They are both dealt with here as one technology.
Technology description: _Vertical takeoff, then horizontal movement of aircraft______

____

3. NASA Center or Centers: Ames_____________
NASA Contact(s): _ John Zuk, 650-604-6568, Ames.

(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)___ Numerous applications in military development programs. Bell XV-3 program proved some of the technology, and this was furthered in the XV-15 and V-22 [programs. Just now (1999) being applied as TRL 9, actual use by military. Best contacts at Bell are Dick Snyder, chief of Research and Technology, (817-280-3054) and Dick Spivey, Military Sales, best source for history (817-280-3749).
____
Company Contact(s): ____
____
(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)____
____

6. Were any enabling or complementary technologies needed to apply this technology (explain)

Needed a breakthrough of a scientific nature, namely developments in aeroelasticity, which is science combining aerodynamics and solid mechanics. Also needed turbine technology development to be practical. Computing power helped solve the associated problems of a scientific nature.

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
Cost reduction ____
____

Safety ____
____

Performance _ Primary benefit is in performance in conducting specific military missions. The ability to lift off vertically, then move forward rapidly, was one that was not feasible with any aircraft. Tiltrotor fills this gap.

Environmental compatibility ____
____

Regulatory compliance ____
____

Other ____
____

8a. When were you first aware of the concept underlying this technology? _1953 Conference on subject

b. When were you first aware of the potential benefits that the application of this technology might produce? _same______________________________

c. On the TRL scale below, where was the technology when you first became aware of the concept? __________________ of the potential benefits? ______________

9.Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1 : Basic scientific/engineering principles observed and reported	1953	
TRL 2 : Technology concept, application, and potential benefits formulated (candidate system selected)	1956	XV-3
TRL 3 : Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	1957	
TRL 4 : System concept observed in laboratory environment (breadboard test)	1958	
TRL 5 : System concept tested and potential benefits substantiated in a controlled relevant environment	1959	XV-3
TRL 6 : Prototype of system concept is demonstrated in a relevant environment	1981	V-22 program
TRL 7 : System prototype is tested and potential benefits substantiated more broadly in a relevant environment	1989	V-22 much improved
TRL 8 : Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	1989	“
TRL 9 : Operational use of actual system tested, and benefits proven	1999/ 2000	Deployment of Osprey

10. Was the technology advanced as part of a NASA focused program? Yes ____ No ___
If yes, which one(s)__XV-3 NO – military. XV-15 was NASA __________

11. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. Numerous technology developments were needed, as noted in 6.
____

(10) 12. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted.

__ There was a great deal of testing done by NASA over the life of these programs, primarily involving Langley facilities (VSTOL tunnel, Transonic Dynamic Tunnel) Ames Vertical Motion Simulator and actual tests at Ames.

13. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? ___________________________
Have history

14. Do you have any other information (e.g., cost through TRLs, etc.)?

This research was relatively inexpensive, considering the developments. (About $50 million spent by NASA.) Demonstrations were particularly important over the life of the programs. It was invaluable to be able to demonstrate the tiltrotor technology.

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1.Team interviewer: _____J. J. Smith___________________________________
Date of interview: ____Sept 15, 1999_______________

2. Name of technology ____ Airframe-Aerospace Vehicle Configurations-Supercritical Wing

Technology description: ___(More efficient wing design)

3. NASA Center or Centers:____Langley__________________________________
NASA Contact(s): _ Dennis Bartlett, Langley, 757-864-1916

(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)_1982..A-310 (First US was Cessna Citation V.) Boeing Douglas did not use till 777.____
Company Contact(s): No contacts provided from the early days as these people have retired for the most part. Mentioned Frank Lynch at B/D Long Beach (no phone) as a current contact.

(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)_______None____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?____________No____

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
Cost reduction Cost reduction due to performance improvement. Not direct objective.

Safety

Performance Basic. Allowed faster and more efficient wing performance.

Environmental compatibility ____
____

Regulatory compliance ____
____

Other ____
____

8a. When were you first aware of the concept underlying this technology? Early 1960's

d. When were you first aware of the potential benefits that the application of this technology might produce? ___________________same_____
e. On the TRL scale below, where was the technology when you first became aware of the concept? __________________ of the potential benefits? ______________

9.Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1 : Basic scientific/engineering principles observed and reported	62/63	
TRL 2 : Technology concept, application, and potential benefits formulated (candidate system selected)	64	
TRL 3 : Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	65	
TRL 4 : System concept observed in laboratory environment (breadboard test)	66	
TRL 5 : System concept tested and potential benefits substantiated in a controlled relevant environment	67	
TRL 6 : Prototype of system concept is demonstrated in a relevant environment	68/69	
TRL 7 : System prototype is tested and potential benefits substantiated more broadly in a relevant environment	68/69	
TRL 8 : Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	1981	
TRL 9 : Operational use of actual system tested, and benefits proven	1982	

10. Was the technology advanced as part of a NASA focused program? Yes ____ No X
If yes, which one(s)____

11. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. ____The technology was on the shelf for a long time since the application of a wing requires a bottom up design, and it can't just be added to a plane that exists. Airbus was first in the commercial application, and Citation V in business.

12. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. _ NASA conducted numerous flight tests and wind tunnel tests in the late 1960's and early 1970's. The wind tunnel tests were conducted at Langley, the flight tests at Dryden.

15. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? ___________________________
Nothing specific, suggested library search.

14. Do you have any other information (e.g., cost through TRLs, etc.)? ______No

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1.Team interviewer: _J.J.Smith____
Date of interview: 8/31/99______________________

2. Name of technology _GA Wing: Advanced General Aviation Wing, basically with

Technology description: Improved laminar flow and stall/spin resistant wing tip design.

3. NASA Center or Centers: Langley____
NASA Contact(s): ___ Bruce Holmes, Lanagley, 757-864-3863. Email b.j.holmes@larc.nasa.gov
(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)___)
Numerous applications of technology have been made, particularly in 4 aircraft. Lancair Columbia, Cirrus SR20, Citation jet series (II) and Piajiet (sp) Avanti P-180.
Company Contact(s): _ Company contacts are Lancair, Dieter Koehler 541-923-4775; Cirrus, Dan Vogel 218-727-2737; Cessna Randy Nelson 316-831-3360; Piajiet, Jan Roskam 913-864-4267.

(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)________________________________Above____________________________

6. Were any enabling or complementary technologies needed to apply this technology (explain)?_
Flow Vizualization technology was required to make this technology possible. Before the late 70's, didn't have the technology to visulaize in-flight flow characteristics.

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
Cost reduction ____
____

Safety . Safety was improved greatly by improving spin resistance.
____

Performance ____Most benefit. About 15 to 25% fuel savings_________________
____

Environmental compatibility ____
____

Regulatory compliance ____

____

Other ____
____

8a. When were you first aware of the concept underlying this technology? Spin resistance first in 1975/76. Laminar flow about 1979.

f. When were you first aware of the potential benefits that the application of this technology might produce? ___________same as above____________________

g. On the TRL scale below, where was the technology when you first became aware of the concept? __________________ of the potential benefits? ______________

9.Technology Progression

Technology Readiness Level	Date (Spin resistance)	Laminar Flow
TRL 1 : Basic scientific/engineering principles observed and reported	75/76	79
TRL 2 : Technology concept, application, and potential benefits formulated (candidate system selected)	76	79
TRL 3 : Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	76	80
TRL 4 : System concept observed in laboratory environment (breadboard test)	77	81
TRL 5 : System concept tested and potential benefits substantiated in a controlled relevant environment	80	84
TRL 6 : Prototype of system concept is demonstrated in a relevant environment	80	85
TRL 7 : System prototype is tested and potential benefits substantiated more broadly in a relevant environment	82	87
TRL 8 : Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	?	88
TRL 9 : Operational use of actual system tested, and benefits proven	89	89

10. Was the technology advanced as part of a NASA focused program? Yes ___ No X X
If yes, which one(s)Part of Regulatory and Technical Base_____

11. Did the application of the technology have to wait for a new product to be developed? Yes
If yes, please explain. Not a new product, but needed lower cost technology in the composite aircraft arena.

12. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted.

Yes. Technology underwent wind tunnel testing and flight testing on numerous occasions. These tests were held 90% at Langley, some in Wichita (corporate) and some at Dryden (sp).

13. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? __ Referred to h.p.stough@larc.nasa.gov as a source for a historical review of the SR technology (email request by JJS on Sep2,99) and NASA technical paper TP-2256 on Laminar Flow.

14.
Do you have any other information (e.g., cost through TRLs, etc.)? ______________

From 1975 to 1986, NASA spent about $30 million on this technology. Since 1986, only travel involved in support.

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1.Team interviewer: ____J. J. Smith_________________________________
Date of interview: ___August 30, 99___________________

2. Name of technology __ Design Tools: Flow Visualization

Technology description: _____ Simulates air flow around aircraft. (NASA Ames developed Flow Analysis Software Toolkit (FAST) in the mid 80's and supported it through about 1992. At about that time, other commercially developed packages were introduced and NASA terminated support.)

3. NASA Center or Centers:________Ames___________________________________
NASA Contact(s) Val Watson, Ames, 650-604-6421

(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)____ Early applications were made by Boeing and Ford Motor (1985). A contact at Boeing is David Kerlick in Seattle at 206-865-5051. Recent commercial use has involved commercial software packages, although there might still be some use of FAST
Company Contact(s): ____
____
(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)____
____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?________ The technology started in the 70's and 80's and basically involves a simulation of airflow. Computer graphics developments were crucial to the development of this technology. Silicon Graphics developed its technology coincidentally with this technology.

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
Cost reduction Really performance, but cost reductions were associated, as is the case generally with simulation

Safety ____
____

Performance X. The technology fulfilled a performance need. They were trying to understand buffeting problems in aircraft. Simulation allowed rapid solution of problems..
Environmental compatibility ____
____

Regulatory compliance ____
____

Other ____
____

8a. When were you first aware of the concept underlying this technology? __1975

h. When were you first aware of the potential benefits that the application of this technology might produce? ______________________1975

i. On the TRL scale below, where was the technology when you first became aware of the concept? _____2_________ of the potential benefits? ______________

9.Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1 : Basic scientific/engineering principles observed and reported	72/73	
TRL 2 : Technology concept, application, and potential benefits formulated (candidate system selected)	77/78	
TRL 3 : Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	78/79	
TRL 4 : System concept observed in laboratory environment (breadboard test)	82-85	NOTE: technology was software programs, and it is not feasible to
TRL 5 : System concept tested and potential benefits substantiated in a controlled relevant environment	“	-readily fit into the TRL structure, since that structure relates more to physical systems.
TRL 6 : Prototype of system concept is demonstrated in a relevant environment	“	
TRL 7 : System prototype is tested and potential benefits substantiated more broadly in a relevant environment	“	
TRL 8 : Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	“	
TRL 9 : Operational use of actual system tested, and benefits proven	1985	

Additional enhancements were made from 1985 to 1990, and the program support for FAST was ended in 1992.

10. Was the technology advanced as part of a NASA focused program? Yes ____ No X_
If yes, which one(s)__(Under basic Research and Technology)

11. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. This technology relied on computer graphics and computer developments, before it could develop.

12. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. The technology underwent wind tunnel confirmation testing (comparing visualization model and real data) at NASA Ames, especially involving the F-16 in the 40x80 wind tunnel.

13. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? _

Some review of history is given in Chapter 1 of book, Visual Analysis of Fluid Dynamics (1994) State of the Art in Computer Graphics ISDN 3-540-94164-9 (Springer Verlag?)

14. Do you have any other information (e.g., cost through TRLs, etc.)? _____________

The technology cost about $2 million to develop over the period 82-92

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1.Team interviewer: J. J. Smith______________________________
Date of interview: 8/30/99____________________

2. Name of technology ____ Engine Monitoring Systems.
Technology description: ___ Display based, "intelligent" display of engine performance factors. (eg. Temp shown not as value but as comparison to ideal .)

3. NASA Center or Centers:____Langley______________________________________
NASA Contact(s): Terry Abbott, 757-864-2009 at Langley

(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)____None yet________________________________
____
Company Contact(s): ____
____
(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)____
____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?____None____
____

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?

Cost reduction: Efficiency/cost benefits, as engine shutdowns etc. are done more appropriately with the EMS technology

Safety Primary benefit. About 47% of engine errors missed with standard readout systems, and none with this technology.

Performance ____
____

Environmental compatibility ____
____

Regulatory compliance ____

Other ____
____

8a. When were you first aware of the concept underlying this technology? _1987
  j. When were you first aware of the potential benefits that the application of this technology might produce? ________________1987
  k. On the TRL scale below, where was the technology when you first became aware of the concept? __________1987 of the potential benefits? ________1987

9.Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1 : Basic scientific/engineering principles observed and reported	1987	
TRL 2 : Technology concept, application, and potential benefits formulated (candidate system selected)	1987	
TRL 3 : Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	1988	
TRL 4 : System concept observed in laboratory environment (breadboard test)	1988	
TRL 5 : System concept tested and potential benefits substantiated in a controlled relevant environment	1989	
TRL 6 : Prototype of system concept is demonstrated in a relevant environment	1990	
TRL 7 : System prototype is tested and potential benefits substantiated more broadly in a relevant environment	1990	
TRL 8 : Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	1995	
TRL 9 : Operational use of actual system tested, and benefits proven	NA	

10. Was the technology advanced as part of a NASA focused program? Yes ____ No X
If yes, which one(s)__Part of Base Aeronautics program.

11. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. _______________________NO_________________________
____

12. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. Langley testing in Simulator and airplane.

16. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? ___________________________

A report on design is available TP 2960

17. Do you have any other information (e.g., cost through TRLs, etc.)? _____________

This development was fairly inexpensive, with NASA spending about $200,000. (Abbott wrote a paper on the subject while a student.)

There is a NASA patent and Honeywell and others are interested, but no agreement reached on valuation.

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1.Team interviewer: J. J. Smith____________________
Date of interview: September 17, 1999

2. Name of technology _ Aerospace Vehicle Configurations – Electro Expulsive DeIcing.

Technology description: ____ Inflight critical surface ice clearing system. Ice is pulverized and is expelled.

3. NASA Center or Centers:__Ames
NASA Contact(s): __John Zuk 650-604-6568, Ames.

(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)_Just now being applied. Tied up in budget problems of military.
Ice Management Systems in California is doing applications for the military. Contact is Dick Olson, number to be provided.
Company Contact(s): ____

____
(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)_none____

____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?__ Needed development of the phyrester, a pulsed solid state electrical switch.

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?

Cost reduction ____

____

Safety ____

____

Performance Primary benefit is in performance and related benefit in safety. Certain smaller military aircraft had limitations for operation in icing conditions. This technology removed critical surface ice, with resulting performance improvement. Safety was minor, and would only be improved for cases of inadvertent of forced flight into icing conditions

Environmental compatibility ____

____

Regulatory compliance ____
____

Other ____
____

8a. When were you first aware of the concept underlying this technology? _1983

l. When were you first aware of the potential benefits that the application of this technology might produce? __________1983
m. On the TRL scale below, where was the technology when you first became aware of the concept? ______1 of the potential benefits? ______________

9.Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1 : Basic scientific/engineering principles observed and reported	1983	
TRL 2 : Technology concept, application, and potential benefits formulated (candidate system selected)	1983	
TRL 3 : Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	1984	
TRL 4 : System concept observed in laboratory environment (breadboard test)	1985	
TRL 5 : System concept tested and potential benefits substantiated in a controlled relevant environment	1986	
TRL 6 : Prototype of system concept is demonstrated in a relevant environment	1987	NASA patent
TRL 7 : System prototype is tested and potential benefits substantiated more broadly in a relevant environment	1993	
TRL 8 : Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	1993	
TRL 9 : Operational use of actual system tested, and benefits proven	1999	

10. Was the technology advanced as part of a NASA focused program? Yes ____ No X_
If yes, which one(s)__Old R&T budget.________________________

11. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. __see 6 above____
____

12. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted.   No, testing was military.

13. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? _No. Background to be sent.

18. Do you have any other information (e.g., cost through TRLs, etc.)? _____________

Delay in implementation (TRL 9) caused by military budget factors. Military had no budget classification for things like deicing, and needed discretionary money to fix other problems related to aircraft. If funds were not tied up, TRL 9 might have been achieved earlier.
This development was very inexpensive and has filled a gap in military capability of certain aircraft.

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: Catherine Schulz
   Date of interview: 9/24/99

2. Name of technology Carbon-6 Thermal Barrier
   Technology description: A braided carbon-fiber thermal barrier designed to be used in solid rocket motor nozzle joints

3. NASA Center or Centers: NASA Glenn Research Center
   NASA Contact(s): Bruce Steinetz: (216) 433-3302, FAX (216) 433-5170,
   E-mail: Bruce.M.Steinetz@lerc.nasa.gov
   (Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)

   Company Contact(s):

(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)

6. Were any enabling or complementary technologies needed to apply this technology (explain)?
   Thiokol asked Glenn if the fiber preform seal would work for in solid rocket motor nozzle joints. The preform seal did not so a new barrier had to be developed.

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
   Cost reduction

   Safety The technology will be used to fulfill a non-life threatening safety need.

   Performance

   Environmental compatibility

Regulatory compliance ____
____

Other ____
____

8a. When were you first aware of the concept underlying this technology? _______________

n. When were you first aware of the potential benefits that the application of this technology might produce? _______________________________

o. On the TRL scale below, where was the technology when you first became aware of the concept? __________________ of the potential benefits? ______________

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported	1997	
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)		
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)		
TRL 4: System concept observed in laboratory environment (breadboard test)	Early '98	
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment	Aug. '99	Tested the barrier at 1/5th scale, it worked flawlessly
TRL 6: Prototype of system concept is demonstrated in a relevant environment		
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment		
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment		
TRL 9: Operational use of actual system tested, and benefits proven		

9. Was the technology advanced as part of a NASA focused program? Yes ____ No __X_
If yes, which one(s)____

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. ____
____

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. ____

12. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? ___________________________

13. Do you have any other information (e.g., cost through TRLs, etc.)? _____________

<u>Feasibility Assessment of Thermal Barrier Seals for Extreme Transient Temperatures,</u> NASA/TM—1998-208484, Bruce M. Steinetz, Patrick H. Dunlap, Jr.July 1998.

<u>Development of Thermal Barriers for Solid Rocket Motor Nozzle Joints,</u> Bruce M. Steinetz and Patrick H. Dunlap, Jr., presented at the 35th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, June 20-24, 1999.

NASA Ames 7/27/99

Case History – DIRECT TO

Heinz Erzberger
650 604-5425

May 1998 TRL 1 to TRL 4, close to 5

Fall 1999 TRL 6
daily operation nine months from now (now = 7/99)

Based on CTAS, conflict probe and trajectory analysis

Solve a conflict without creating a new one—noted that many conflicts resolved by sending aircraft on direct route to next fix.

Direct route has to be time saving (taking into account winds and aircraft performance)

Today—TRL 4

5/98—TRL 1

TRL 4 –7/99

TRL 5 9/99

TRL 6 fall 1999 or early 2000 (projected)

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: ____

Date of interview: _10/15/99____________________

2. Name of technology: Low Emissions Combustors

Technology description: Two-stage combustors featuring double-annular dome, shingle liners, and multiple-passage flow prediffusers

3. NASA Center or Centers: NASA Glenn Research Center

NASA Contact(s): Dan Sokolowski, (216) 433-3216, Daniel.E.Sokolowski@lerc.nasa.gov
Dan Bulzan (216) 433-5848, Dan.L.Bulzan@lerc.nasa.gov
(Include names, phone and fax numbers and email addresses)

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4. First Aeronautics Application (include company, aircraft make and model, and specifics on application) General Electric Aircraft Engines, GE90 engine, used on Boeing 777

Company Contact(s): General Electric, Dave Burrus
(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)___None____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?
Yes. Shingle liner- developed by Air Force, fuel injectors and staging valves.

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?

Cost reduction (Secondary) Longer life hardware

Safety More reliable combustors with fewer in-flight shutdowns

Performance _Higher turndown ratio enabling wider engine operating limits. Dramatically shortened_combustor length providing weight reductions and improved engine specific fuel consumption.____

Environmental compatibility _reduced pollutant emissions____

Regulatory compliance _Developed technology to meet EPA and ICAO Standards____

____

Other ____
____

8a. When were you first aware of the concept underlying this technology? 1972

p. When were you first aware of the potential benefits that the application of this technology might produce? 1975

q. On the TRL scale below, where was the technology when you first became aware of the concept? 1/2 of the potential benefits? 3/4

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported	1972	Experimental Clean Combustor Program Started
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)		
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)		
TRL 4: System concept observed in laboratory environment (breadboard test)	1976	Sector testing under Clean Combustor Program
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment	1978	Start of Energy Efficient Engine Project-preliminary design of double-annular combustor
TRL 6: Prototype of system concept is demonstrated in a relevant environment	1982	Full-Annular Combustor Demonstrated under Energy Efficient Engine Project
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment	1984/84	Full Annular Combustor evaluated in core engine and integrated core engine testing
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment		“Need to ask GE”
TRL 9: Operational use of actual system tested, and benefits proven		“Need to ask GE”

9. Was the technology advanced as part of a NASA focused program? Yes X No ___
If yes, which one(s) Energy Efficient Engine Project

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. Yes, GE 90 engine development required the development of the Boeing 777 aircraft that required two high-thrust, high performance engines with low emissions

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. No

14. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? Yes, There are numerous contractor reports, technical society reports and presentations, and NASA reports.

15. Do you have any other information (e.g., cost through TRLs, etc.)?
No

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: Received by Cathy Schulz
   Date of interview: Received on September 7, 1999 from David Bowles.

2. Name of technology: Nondestructive Evaluation (NDE) for Aging Aircraft
   Technology description: NDE instrumentation/technology for detecting disbonds, corrosion, and cracks, in metallic fuselage structure that is more reliable and cost effective than today's current inspection technology

3. NASA Center or Centers: NASA Langley Research Center

   NASA Contact(s): Dave Bowles, (757) 864-3095, d.e.bowles@larc.nasa.gov
   Bill Winfree, (757) 864-4963, w.p.winfree@larc.nasa.gov
   (Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application) Disbond, corrosion, and crack detection in metallic fuselage structure.

   Company Contact(s): Boeing, Lockheed Martin, Air Force. In a conversation with Dave, at a later date, Dave indicated that Bill Winfree would know the company contacts.
   (Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?
   None

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7. What needs did this technology fulfill? How did the technology meet or address the identified needs?

Cost reduction (Secondary) cheaper, less time consuming

Safety (Primary) more reliable, better resolution than currently available systems

Performance ____

Environmental compatibility _______________________________________

Regulatory compliance ____

Other ____
____

8a. When were you first aware of the concept underlying this technology? Prior to 1992.

b. When were you first aware of the potential benefits that the application of this technology might produce? 1992/1993

c. On the TRL scale below, where was the technology when you first became aware of the concept? 2/3 of the potential benefits? 3/4

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported		
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)	1992/1993	***Milestones Accomplished***
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)		
TRL 4: System concept observed in laboratory environment (breadboard test)	1994/1995	***Milestones Accomplished***
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment		
TRL 6: Prototype of system concept is demonstrated in a relevant environment	1996/1998	***Milestones Accomplished***
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment		
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment		
TRL 9: Operational use of actual system tested, and benefits proven		

9. Was the technology advanced as part of a NASA focused program? Yes X No ___
If yes, which one(s) Advanced Subsonic Technology (AST) Program

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. Yes, Commercially available NDE instruments had to be developed. One is already on the market and two others are being developed (see question # 4)

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. Field testing of NDE prototype instruments were conducted at the FAA NDE Validation Center, airframe manufacturers (Boeing, Lockheed), and at the airforce.

12. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? Joint DOD/NASA/FAA Conference on Aging Aircraft (1997, 1998, 1999), numerous technical presentations at NDE technical specialist conferences

13. Do you have any other information (e.g., cost through TRLs, etc.)?

Commercial Product Licensing Agreements:

- Krautkramer Branson Inc.
  - Low cost eddy current crack detection probe and thickness gauge.
- Foerster Instrumentation Inc
  - Rotating Self-Nulling Probe for detection of small cracks under rivet heads
- ThermTech Services, Inc.
  - Thermal Line Scanner Technology for corrosion detection

Additional information from internet search:

"The development of NDE technologies from concept to commercialization can take two to five years" Overview of the National Aeronautics and Space Administration's Nondestructive Evaluation (NDE) Program, Edward R. Generazio, Ninth Annual Symposium on Nondestructive Characterization of Materials, Sydney, Australia, June 28--July 2, 1999.

NASA Langley Research Center, 12/8/1994, Aging Aircraft-K.B. Probe
http://lisar.larc.nasa.gov/ABSTRACTS/EL-1996-00145.html

Smart Ultrasonic System for Aircraft NDE (SUSAN)
http://www-nesb.larc.nasa.gov/NESB/ndetasks/susan.html

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: ______DJP____
   Date of interview: ____

2. Name of technology __Particle Imaging Velocimetry (PIV)________________________
   Technology description: _measures air velocity inside engines_________

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3. NASA Center or Centers:______Glenn____
   NASA Contact(s):
   Carolyn Mercer (216) 433-4311 or Mark Wernet (216) 433-3752

(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)_______compressor tests____

   Company Contact(s): ____has not yet gone to industry_________________________

(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)___compressor tests____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?__yes: particle generation, frame straddling recording, and light delivery to bring inside engine._______________________________

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
   Cost reduction __tests are done more quickly ___________________________

   Safety __learning things about engine stall_________________________________

   Performance __learning things about engine stall that allows designing better performance and validating codes ____

   Environmental compatibility ____

Regulatory compliance ____

Other ____
____

8a. When were you first aware of the concept underlying this technology? ___late 80's___

r. When were you first aware of the potential benefits that the application of this technology might produce? _____early 90's________________

s. On the TRL scale below, where was the technology when you first became aware of the concept? ___________________ of the potential benefits? _______________

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported	late 80's	
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)	late 80's	
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	early 90's	
TRL 4: System concept observed in laboratory environment (breadboard test)	mid 90's	
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment	1998	first test in compressor
TRL 6: Prototype of system concept is demonstrated in a relevant environment	1998	
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment	1999	
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	1999	
TRL 9: Operational use of actual system tested, and benefits proven	1999	

9. Was the technology advanced as part of a NASA focused program? Yes ____ No _X__
If yes, which one(s)____

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. __yes, the enabling technologies described in question 6_______________
____

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted.

_Glenn_______________________________________ground testing in high speed axial and centrifugal compressor rigs.
____

16. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? ___yes, to send me________________

to send me a paper

17. Do you have any other information (e.g., cost through TRLs, etc.)? __no____________

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: Cathy Schulz____
Date of interview: 9/29/99___
*Note: includes information gathered from documents found on the web.

2. Name of technology Development of Propfans______________________________________
Technology description: A new engine using fewer blades than older engines 10-20 instead of closer to 50, blades have an aerodynamic sweep to them, propfan was very fuel efficient burning 30-40% less fuel. (Technology has also been known as: the unducted fan, open rotor or ultra high bypass engine.1)

3. NASA Center or Centers: NASA Glenn_______________________
NASA Contact(s): George Stefko. (216) 433-3920, (216) 433-8000 Fax, george.stefko@lerc.nasa.gov.
(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application) GE test flew them on 727s, but first actual application was a modified version of the propfan which was used on the Boeing 777 as the GE90 engine. On Nov. 11, British Airways received their first 777 powered by the GE90 engine (4).

Company Contact(s): GE: Bob Conway; Joe Osani (513) 243-4984 who was company's rep to NASA at the time of the program; and Carol Cash (440) 777-9545 who is the current company contact (probably will know who to speak with from GE).
(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application) Pratt & Whitney along with Allison (they teamed together) also did some work with the technology. Pratt contact: Lou Flaherty: Flaherty@PWFL.com He's a relatively new rep, the one who was there during the program is retired.

6. Were any enabling or complementary technologies needed to apply this technology (explain)?
According to George, there were several technologies that made this one possible. First were better analysis techniques that were not previously available. These techniques and new instrumentation allowed one to see where the problems/failures were with in the engine models during testing. Aeroelastic Technology was important because of flutter, Computational Fluid Dynamics were helpful as well.

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?

Cost reduction Cost reduction was the primary need. Aircraft operational costs were decreased because the engine was more fuel efficient than other engines.

Safety ______________________________

Performance ______________________________

Environmental compatibility ______________________________

Regulatory compliance A secondary need was in response to noise regulations – the engine had to meet certain criteria, and did.

Other ______________________________

8a. When were you first aware of the concept underlying this technology? 1978

t. When were you first aware of the potential benefits that the application of this technology might produce? 1978

u. On the TRL scale below, where was the technology when you first became aware of the concept? 1 of the potential benefits? 1

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported	1978	Date program started
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)	1980-81	In ’81 it turned into a focused program.
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	’81 – 82	(1) GE came and did study/component test work
TRL 4: System concept observed in laboratory environment (breadboard test)		
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment	85-86	(1) NASA and GE coop ground test UDF
TRL 6: Prototype of system concept is demonstrated in a relevant environment	Aug 86-’87	(1) Flight tests conducted by GE/Boeing of modified engine on 727 (2) Program reached its goals after flight tests verified the readiness of advanced propulsion technology for commercial engine development.
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment	Feb 89	(3) NASA did more tests of the propfan for noise
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	Feb 95	(4) GE flight tested the GE-90 engines on a 777, engine certified by FAA
TRL 9: Operational use of actual system tested, and benefits proven	Nov. 95	(5) 777 with GE90 Engines delivered to British Airways

9. Was the technology advanced as part of a NASA focused program? Yes _X___ No ___
If yes, which one(s)_It became the Advanced Turboprop Program, it started as a base program. ____________________

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. When asked, George referred back to analyses techniques that made the development of the technology feasible along with CFD and aeroelastic capabilities, and said laser wasn’t around. ____________________

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. Yes, it went through several different tests at NASA. Langley and Ames were involved with tests to see if the engine could be mounted to the aircraft, wind tunnel tests were originally conducted at Langley and completed at Glenn. Inflight model testing was done at Dryden.

18. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? Best source is a hardbound book written on the program, "Advanced Turboprop Program", a 120-page book written by Roy Hager & Deborah Vrabel in 1988.

19. Do you have any other information (e.g., cost through TRLs, etc.)? Because fuel costs eventually declined before the technology was applied, the engine was never applied as designed and tested by NASA. It evolved into a ducted engine and was then used by Boeing on the 777. There is a follow-up to the technology – counter-rotating turbofans for cruise missiles tested at NASA Ames.

The propfan had its origin in NASA's Aircraft Energy Efficiency program, begun in 1975. 1 NASA Lewis, along with the NASA/Industry Advanced Turboprop Team, won the 1987 Robert J. Collier Trophy. 2

1. Toward Future Flight – printed from the 1987 issue of NASA's Magazine, SPINOFF.
2. NASA's Advanced Turboprop Wins Esteemed Collier Trophy, Space Link, Release: 88-59, May 4, 1988.
3. NASA Final Propfan Program Flight Tests Conducted, Release 89-64, May 1, 1999.
4. GE Certifies GE90 at 84,700 Pounds Thrust, GEAE-06, February 2, 1995.
5. British Airways Receives First GE-90 Powered Boeing 777, GEAE-74, November 11, 1995.

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: ________DJP____
   Date of interview: _______10/7/99____

2. Name of technology ______Runway Grooves_____________________________________
   Technology description: __channels or slots cut transversely into surface of runway to optimize water drainage from crown to edges. Improves braking performance.

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3. NASA Center or Centers:___Langley____
   NASA Contact(s):
   Tom Yager 757 864-1304

(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)______Wallace Airport Chinoteque, VA 1968_rebuilt runway test section in asphalt and concrete. ____

   Company Contact(s): __American Grooving and Grinding Association - John Roberts ________518 731-7450____
(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)__Proved at Wallace Airport. First commercial application was at Kansas City, KN Airport , then at Washington National (DCA) 1970-71
____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?_Had to wait for machines to be developed that could three foot long grouved. Original machines were hand operated at the beginning.__Only waited a few months.__

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
   Cost reduction ____
   ____

   Safety __Reduced accidents in runways and highways dramatically. Applied to curves in highways in California. Reduced accidents from 10 per month to zero.
   ____

   Performance _____ Enables quicker stops, and reduces chances of veering –off accidents. ___
   ____

   Environmental compatibility ____
   ____

Regulatory compliance ____
____

Other ____
____

8a. When were you first aware of the concept underlying this technology? ____1965______

v. When were you first aware of the potential benefits that the application of this technology might produce? ______1968_____________________

w. On the TRL scale below, where was the technology when you first became aware of the concept? _____1967_________ of the potential benefits? _______________

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported	1966-1967	
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)	1967	
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	1967	
TRL 4: System concept observed in laboratory environment (breadboard test)	1666-1967	
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment	1967	Wallace Airport, tested 18 different groove configurations
TRL 6: Prototype of system concept is demonstrated in a relevant environment	1968	Tested on California Highways
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment	1969	International Conference discussed testing at Wallace
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	1970	Kansas City Airport, Washington National
TRL 9: Operational use of actual system tested, and benefits proven	1970	

9. Was the technology advanced as part of a NASA focused program? Yes ____ No _X__
If yes, which one(s)____

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. ______ Waited for machines that could make larger grooves __________

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. At Wallace Airport, Chinoteque, VA

20. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? ___Yes, to be send to me, a NASA Fact Sheet

21. Do you have any other information (e.g., cost through TRLs, etc.)? _____________

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: ___djp________________________________
   Date of interview: ____9/21/99__________________

2. Name of technology ____Surface Movement Advisor (SMA) ___________________
   Technology description: Monitors surface movement of aircraft on airport and allows tower to better direct and schedule these movements.

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3. NASA Center or Centers:____Ames____
   NASA Contact(s): Yuri Gawdiak (650) 604-4705, ygawdiak@mail.arc.nasa.gov
____
____

(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)
   Applied at Atlanta Hartsfield Airport as, what the FAA calls a production prototype (demonstrator) in December 1996 and has been operating smoothly ever since. 24 hours/day, seven day/week.

   Company Contact(s): FAA - Ricardo Parra (202) 863-2680 x 221
____

(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application) ____N/A____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?
   COTS database system, COTS case tools for development tracking and maintenance . The availability of high speed networks were critical to the application of SMA. There were available and did not require NASA to wait for their development.

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?

Cost reduction There is significant cost reduction due to improvement of real-time scheduling of ground movements of <u>all</u> aircraft. Advantage to passengers because of reduced taxi time. Advantage to operators in reduced maintenance requirements due to reduced cycle time and less wear and tear of engines and landing gear.

Safety ____

Performance ____

Environmental compatibility

Reduced noise and pollution because of reduced operating time due to better scheduling of ground movements. ____

Regulatory compliance ___ N/A ____
____

Other ____
____

8a. When were you first aware of the concept underlying this technology?

The FAA came to NASA around 1993-94 with need for better coordination separation of ground movements.

x. When were you first aware of the potential benefits that the application of this technology might produce? ________________________________

y. On the TRL scale below, where was the technology when you first became aware of the concept? __________________ of the potential benefits? ______________

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported	1994-1995	
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)	1995	
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	1995	
TRL 4: System concept observed in laboratory environment (breadboard test)	1995	
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment	1996	
TRL 6: Prototype of system concept is demonstrated in a relevant environment	Summer 1996	
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment	November 1997	
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment	November 1997	
TRL 9: Operational use of actual system tested, and benefits proven	December 1997	Installed at Hartsfield

9. Was the technology advanced as part of a NASA focused program? Yes _X_ No ___
If yes, which one(s)___AATT____

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. __no____

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. It as installed at Atlanta Hartsfield for demonstration and testing of its real-time management capability. ________________

22. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? Yes, to be furnished by NASA. _

23. Do you have any other information (e.g., cost through TRLs, etc.)? SMA has been incorporated into a portion of the FAA free-flight program. ______________

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: ____________DJP____
   Date of interview: ____9/27/99 ______________________________

2. Name of technology ___X-36____
   Technology description: __Tailless, agile fighter, for National Security needs. _______

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3. NASA Center or Centers:___Ames ____

   NASA Contact(s): Mark Sumich 650 604-6193
(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)__Did not go beyond a test bed for systems at NASA
____

   Company Contact(s): ____
(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)____
____

6. Were any enabling or complementary technologies needed to apply this technology (explain)?__Thrust Vectoring Nozzle (TVN), new flight control computer (developed by McDonnell Douglas, see TVN case history), CAD, rapid prototyping process, soft tooling (carbon fiber tooling),
____

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
   Cost reduction ____
   ____

   Safety ____
   ____

   Performance ____
   ____

   Environmental compatibility ____
   ____

Regulatory compliance ____
____

Other __Demonstration of a survivable, agile, tailless fighter, for National Security needs.
____
____

8a. When were you first aware of the concept underlying this technology? ____1989 ____

z. When were you first aware of the potential benefits that the application of this technology might produce? _______Immediately________________________

aa. On the TRL scale below, where was the technology when you first became aware of the concept? ________1__________ of the potential benefits? __________1____

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported	1989	variety of initial designs
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)	1992	actual X-36 design
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	1993	
TRL 4: System concept observed in laboratory environment (breadboard test)	1994	wind tunnel testing
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment	1995	full-up simulation
TRL 6: Prototype of system concept is demonstrated in a relevant environment	1997	first flight, additional flight are performed as test bed for new systems
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment		
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment		
TRL 9: Operational use of actual system tested, and benefits proven		

9. Was the technology advanced as part of a NASA focused program? Yes __X__ No ___
If yes, which one(s)__classified____

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. ______TVN, flight computer that was fast enough, aerodynamic database (CFD), a combination of flight control laws and wind tunnel testing had to be built up to be able to perform simulation correctly ___________________________________

____

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. No, tests at Dryden

24. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? ___Yes, but must have our human resources person send proof of my US citizenship. Not a classified report but non-US citizens CANNOT see or handle it. Send to:

Mark Sumich
NASA Ames Research Center
Mail Stop 237-2
Moffett Field, CA 94035

25. Do you have any other information (e.g., cost through TRLs, etc.)? _____________

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: _______DJP____
   Date of interview: __9/27/99____

2. Name of technology __Thrust Vectoring Nozzle (TVN)___________________________
   Technology description: ___On a tailless plane nozzle used for guidance control. ________

3. NASA Center or Centers:__ Ames_________________________
   NASA Contact(s):

Mark Sumich, 650 604-6193
(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)____First flight use of nozzle was on X-36, in May 1997. X-36 is a research vehicle test bed. First commercial application is to be on the unmanned combat aerial vehicle (UCAV) now being built by Boeing, expected to first fly in 2001. ___

   Company Contact(s): __Leahy (DARPA) ____________________________________

(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)___Boeing, unmanned combat aerial vehicle (UCAV) remotely operated pilot-less bomber, if 2001 test are successful it would go into production. It uses the TVN for guidance.

6. Were any enabling or complementary technologies needed to apply this technology (explain)?__Because of its instability in flight a very fast control computer needed to be developed. McDonnell-Douglass (before being bought by Boeing) was asked to develop such a computer just for the the TVN which they did in about 18 months. The computer has to cycle control law performance on all control functions 100 X per second. It had to be fast enough and *small* enough to operate the nozzle. ______

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
   Cost reduction ____

   Safety ____

   Performance ____

Environmental compatibility ____
____

Regulatory compliance ____
____

Other _National security. A highly maneuverable tailless fighter reduces observability, and increases survivability, lowers weight, and increases aerodynamic capability. It needed a thrust vector for advanced control. ____________________________________

8a. When were you first aware of the concept underlying this technology? _1989_________

bb. When were you first aware of the potential benefits that the application of this technology might produce? __Immediately ________________________

cc. On the TRL scale below, where was the technology when you first became aware of the concept? _______________ of the potential benefits? ____________

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported	1989	demonstration nozzles
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)	1989	
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	1990	CFD
TRL 4: System concept observed in laboratory environment (breadboard test)	1992	
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment	1994	testing actual nozzle that would be in X-36
TRL 6: Prototype of system concept is demonstrated in a relevant environment	1997 5/1 – 11/12	X-36 tested in full flight demonstration using the TVN
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment		
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment		
TRL 9: Operational use of actual system tested, and benefits proven		

9. Was the technology advanced as part of a NASA focused program? Yes _X__ No ___

If yes, which one(s)______classified____

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. __Flight control computer needed to be developed, not COTS items were used. ____

____

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. ____Flight demonstration in X-36 at Dryden.

26. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? _____Yes, but must have our human resources person send proof of my US citizenship. Not a classified report but non-US citizens CANNOT see or handle it. Send to:

Mark Sumich
NASA Ames Research Center
Mail Stop 237-2
Moffett Field, CA 94035

27. Do you have any other information (e.g., cost through TRLs, etc.)? ______________

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: Cathy Schulz
Date of interview: 10/5/99

2. Name of technology Graphite Fiber Reinforced Polymide Variable Stator Vane Bushings – Tribology.
Technology description: ____________________

3. NASA Center or Centers: NASA Glenn
NASA Contact(s): Chris DellaCorte, (216) 433-6056, (William Jones, the contact indicated, only does space applications. During a brief telephone conversation, he indicated that he hadn't done aeronautics technology in years, and said he was unable to help).

(Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)
Possibly GE with the GE90

Company Contact(s): ____________________

(Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application)____________________

6. Were any enabling or complementary technologies needed to apply this technology (explain)?____________________

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
Cost reduction ____________________

Safety ____________________

Performance Yes – higher temperatures

Environmental compatibility ____
____

Regulatory compliance ____
____

Other ____
____

8a. When were you first aware of the concept underlying this technology? 15 years ago (1984)

dd. When were you first aware of the potential benefits that the application of this technology might produce? _When it was already into practice.________________________________

ee. On the TRL scale below, where was the technology when you first became aware of the concept? _(sounds like 9)___ of the potential benefits? __(sounds like 9)______________

9. Technology Progression

Technology Readiness Level	Date	Basis for this Date
TRL 1: Basic scientific/engineering principles observed and reported	Early 60's	
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)		
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)		
TRL 4: System concept observed in laboratory environment (breadboard test)		
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment		
TRL 6: Prototype of system concept is demonstrated in a relevant environment		
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment		
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment		
TRL 9: Operational use of actual system tested, and benefits proven	Late '70s	

9. Was the technology advanced as part of a NASA focused program? Yes ____ No _X_
If yes, which one(s)__(Not that he is aware of)____________________

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. _No____

____

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. _Doesn't really know._________________

28. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? Said to look up an author by the name of Harold Sliney. (Tried to find papers via the internet on this case technology but was unable to. Also, looked up Sliney and found several articles authored by him, but none were on this particular technology).

29. Do you have any other information (e.g., cost through TRLs, etc.)? _____________

TECHNOLOGY TRACKING FORM
TRL CASE STUDIES

1. Team interviewer: Cathy Schulz
   Date of interview: Thursday, September 30, 1999

2. Name of technology: Fly-by-Light
   Technology description: The replacement of electronic data transmission, mechanical control linkages, and electronic sensors with optical components and subsystems (1).

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3. NASA Center or Centers: NASA Glenn
   NASA Contact(s): Gary Seng, (216) 433-3732, (216) 433-8000 (Fax), Gary.T.Seng@lerc.nasa.gov.
   (Include names, phone and fax numbers and email addresses)

4. First Aeronautics Application (include company, aircraft make and model, and specifics on application)
   Raytheon business jet that is going into production next year ('00). Closest aeronautics application. (He couldn't remember the aircraft make and model when we spoke).
   "a portion of our efforts (not our main line program work for large transports) associated with business jets has been put into a Raytheon Beech 1900D due out next year"

   Company Contact(s): Brian Morrison (508-490-3537 from about 3 years ago).
   (Include names, phone and fax numbers and email addresses)

5. Other Early Aeronautics Applications: (include company, aircraft make and model, and specifics on application) Is being applied on the space side in the X-33 and X-34. Sherry Buschmann is a good contact (she is at NASA Marshall).

6. Were any enabling or complementary technologies needed to apply this technology (explain)?
   Early on, the actual optical fiber itself. Also needed quality optical connectors and sensors. Early on the diodes weren't of high enough quality.

7. What needs did this technology fulfill? How did the technology meet or address the identified needs?
   Cost reduction: Economic benefits would have come from weight savings. There would've been a cost benefit because the high-bandwidth nature of the technology would have allowed for more information to be passed.

   Safety: The technology also would have met safety needs. Optical fibers aren't sensitive to electromagnetic interference. Also, if there were a break in the cable, there would not be a safety problem (sparking). As for military operations, the aircraft would not be affected by pulse wave warfare if it were equipped with Fly-by-Light.

   Performance ______________________________

   Environmental compatibility ______________________________

Regulatory compliance ____

Other ____

8a. When were you first aware of the concept underlying this technology? The team became aware in '75, Gary became aware in the '80s when he joined the program ('85?).

ff. When were you first aware of the potential benefits that the application of this technology might produce? The team was aware right from the start in '75.

gg. On the TRL scale below, where was the technology when you first became aware of the concept? Team became aware at a TRL of 1 of the potential benefits? Same

9. Technology Progression

Technology Readiness Level	**Date**	**Basis for this Date**
TRL 1: Basic scientific/engineering principles observed and reported	1975	When the work on the technology was initiated, according to Gary
TRL 2: Technology concept, application, and potential benefits formulated (candidate system selected)	1975-1980	From 75 to 80 the technology lingered in the 1-2 phase
TRL 3: Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)	1980-85	NASA built schemes for Fly-by-Light. In '85 FOCSI was established. The goal was to take it to TRL 6.
TRL 4: System concept observed in laboratory environment (breadboard test)	'85-'94	"Program eeked along"
TRL 5: System concept tested and potential benefits substantiated in a controlled relevant environment	1994	Open loop flight test conducted at Dryden on F-18.
TRL 6: Prototype of system concept is demonstrated in a relevant environment	*'95-'96*	*Closed loop flight testing was planned for this time period, program cancelled before they reached 6.*
TRL 7: System prototype is tested and potential benefits substantiated more broadly in a relevant environment		
TRL 8: Actual System constructed and demonstrated, and benefits substantiated in a relevant environment		
TRL 9: Operational use of actual system tested, and benefits proven	*2000*	*Raytheon is going to apply a similar form of the technology on its new business jet –scheduled for production in 2000.*

FOCSI: Fiber Optic Control System Integration

9. Was the technology advanced as part of a NASA focused program? Yes _X__ No ___
If yes, which one(s) First 10 years, it wasn't, second 10 years it was a part of AST (Advanced Subsonic Technology) Program.

10. Did the application of the technology have to wait for a new product to be developed? If yes, please explain. No.____

11. Did the technology undergo flight or other testing by NASA? If yes describe tests and identify NASA facility where conducted. Yes – at Dryden. They used an F-18 and performed an "open loop" test. ______________________________________

30. Are there any reports that describe the progression of this technology from its earliest conceptual formulation to its application by the aeronautics industry, or describe its progression through any parts of this sequence? ________________________

Journal called *Signal*. Feb. '94. "FBL age opens with optical sensor fighter control.

Flight International. Jun 8-14, '94. "Test Case" by Guy Norris.

Photonics Spectra. April '95. "Photonics in aerospace transportation".

Aviation Week & Space Technology, Aug.2 '93. "NASA Navy to evaluated sensors in F-18."

NASA TM-100919, "Overview of NASA Research in Fiber Optics for Aircraft Controls" by Gary Seng, Oct., 1988;

NASA TM-106151 "Status of the Fiber Optic Control System Integration (FOCSI) Program" by Robert Baumbick, May, 1993.

The Aviation Week article is from the April 26, 1999 issue and is entitled "Fiber Optic Data System to Debut on 1900D", P. J. Klass, pgs. 66-67.

31. Do you have any other information (e.g., cost through TRLs, etc.)?
Gary kept pointing out that the reason the technology took so long to develop was due to funding. They were never held up by technology, just lack of sufficient funding to move the technology along. Also noted that it (waiting for funding and seeing the program move along so slowly) is frustrating. Mentioned the possibility that the technology would eventually find its way back to aeronautics.

(1) Advanced Subsonic Technology Project, Fly-by-Light/Power-by-Wire Element: http://www.grc.nasa.gov/Other_Groups/AST/fblpbw.htm last udpated 21-Jan-99.

NASA Tests Fiber Optic Sensors for Aircraft Control Systems, http://spacelink.nasa.gov/NASA.News/NASA.News.Releases/Previous.News.Releases/92.News.Releases/92-02.News.Releases/92-02-11

FOCSI home page: http://www.dfrc.nasa.gov/Projects/SRA/focsi.html

FACT home page: http://www.dfrc.nasa.gov/Projects/SRA/fact.html

Fiber Optic Sensors: http://www.grc.nasa.gov/WWW/OptInstr/fibopg_ga.html

Status of the Fiber Optic Control System Integration (FOCSI) Program, Robert J. Baumbick, May 1993, NASA TM-106151

Optical Closed-Loop Propulsion Control System Development, Gary L. Poppel, August 1998, General Electric Aircraft Engines Cincinnati, Ohio 45215, NASA CR-1998-208416 R98AEB237.